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COMPARISON OF POLLUTING POTENTIALS OF LIQUID EMISSIONS FROM MBT PLANTS

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SUMMARY: leachates from two waste management plants which include MBT and an associated landfill have been studied. Leachates have been sampled on different parts of the landfill, and, when possible, process waters have also been sampled. Classical parameters have been measured on all samples and values have been compared: between leachates of the same site, between sites, and to literature values. Leachates show different behaviours depending on the compound: some values are typical of young waste, while others are more representative of old, stabilized waste.

1. INTRODUCTION

Mechanical biological treatment (MBT) of municipal solid waste (MSW) is presently largely developing in France, with different purposes:

- reducing the volume and stabilizing the waste prior to landfilling,
- recovering of organic matter through compost which can be used in agriculture,
- generating renewable energy (biogas) with anaerobic digestion.

The two first objectives can be achieved either by anaerobic or aerobic biodegradation (composting). An important advantage of MBT is –in theory– the reduction of the gaseous and liquid emissions from the storage of stabilized waste. Evaluation of this reduction can be related to a given stage of stabilization of waste.

Since 2006, INERIS conducted several measurement campaigns on different aerobic MBT plants and landfills in France in order to assess the environmental benefits obtained by treating the waste, compared to classical landfilling of untreated waste.

2. MATERIALS AND METHODS

2.1 Description of the sites

Both plants undergo an aerobic stabilization of the waste prior to landfilling, and both plants have their own landfill. Meanwhile, there are differences in both the mechanical and biological treatment. Leachates are not rejected to surface waters but treated, either on-site or off-site.

2.1.1 Site A

Site A is situated in a rather rural area of France, and receives the waste from approximately 40,000 people. The plant is surrounded by fields and woods.

On this site, there is no grinding of the waste at the entrance of the plant. Waste undergo a first sorting: the large fraction (>450 mm) goes directly to the landfill (cell 1), the fine fraction (<70 mm) is sent to the composting area. The intermediary fraction goes to a rotating tube where it is humidified, and stays for 2 to 3 days. There, aerobic degradation starts. This fraction is then sorted. The larger fraction is mainly constituted of plastics: it is baled and sent to cell 2. The finer fraction (<50 mm) goes to the composting windrows but separately from the first fine fraction.

Windrows are aerated by forced air blowing under the material. The controlled composting process generally lasts 4 weeks. After this first step, waste is deposited in windrows for a maturation step of several months. The two composted fractions are then deposited together into the cell n° 2.

Therefore, this site has four leachate ponds :

- pond n° 1 corresponds to the larger fraction), which contains very little organic matter,
- pond n° 2 receives leachates from the stabilized fine fraction,
- pond n° 3 receives leachates from the intermediary fraction, constituted mainly by plastics, which can contain a little degradable matter,
- pond n° 4 receives the waters from the different steps of the process (pre-degradation, composting, maturation...)

Leachates from all four ponds have been sampled.

2.1.2 Site B

Site B is located in a mixed area (rural and urban parts), not far from the sea. On this area, there are separate collections of packing and biowaste. Residual waste which enters the stabilization plant therefore contains less organic matter than typical municipal waste. The plant treats the waste from around 180,000 people. The plant is located in the suburb of the main town, and has close neighbours.

When arriving in the plant, residual waste is first grinded and iron is separated. The waste is then homogenised and humidified, and goes to composting tunnels for (3 + 2) weeks. Waste is automatically transported and turned in the tunnels, and conditions (aeration, temperature, humidity) are controlled. After 5 weeks, stabilized waste goes to the landfill which is situated at a few kilometres from the plant.

The landfill has two different areas: the first one is constituted by a single large cell, which received mixed untreated waste until 2006. The second area is constituted of smaller independent cells which receive only stabilized waste since 2006. Leachates are collected separately from the two zones, but goes to the same pond. There is a water treatment device on the landfill. Samples are labelled as follows:

- “Leach. K1” samples were taken at the outlet tube from the old cell called K1,
- “Leach. K2” samples were taken at the common outlet of the new cells of the K2 area.

2.2 Sampling and analysis

Different leachates were sampled on the two sites, in order to compare the pollution potential between different situations:

- on the first site, both the process waters and leachates coming from the 3 sections containing the different sorted waste were studied,

- on the second site, leachates from the two different sections, corresponding to the older untreated waste, and the younger stabilized waste were sampled separately.

Samples have been taken on each pond, directly at the collector outlet, stabilized if needed, kept at low temperature and sent to the analytical laboratory within 2 days.

On all leachate samples, several analyses were run:

- the classical parameters (pH, conductivity, organic contents, salts and metals) were measured on either unfiltered or filtered samples, depending on the standardized method,
- suspended matter was examined by scanning electronic microscopy (SEM), and X-ray microprobe.

Suspended matter content of young leachates can be very high and the study of this specific fraction can bring useful information as it represents the finest fraction of the solid phase, though it is not often reported (see an example in Ziyang & Youcai, 2007). In addition to the “classical” parameters given previously, we have studied the refuse phase of leachate filtration by electronic microscopy. Two different preparation processes were run: filtration on cellulose membranes of porosity 0.45 μm , or deposition of 5 drops of leachates on a glass slide and slow drying at ambient temperature. Samples were then examined in the chamber of the SEM and elementary analysis was performed with the micro-X-ray probe.

3. RESULTS AND DISCUSSION

Variation in the values of the different parameters depend on the treatment process, on the sorting which can be made, on the type and age of landfilling, and eventually on the season during which waste has been collected and treated. The complete result set is given in Table 1.

Table 1. Values of the parameters measured on the different leachate ponds of the two sites, compared to literature values

	Site A				Site B		Typical values	
	Pond 1	Pond 2	Pond 3	Pond 4	Leach K1	Leach K2	Kjeldsen	Robinson
pH (1)	7.2	7.95	7.6	7.1	8.05	8.6	4.5-9	7.5-8.5
Conductivity mS/cm (1)	9.14	30.4	18.8	18.5	18	7.98	2.5-35	10-20
Suspended matter, mg/l	12	44	68	300	14	110		
COD, mg O ₂ /l	1 240	12 800	5 680	7 200	3 010	8 940	140-152 000	1 000-5 000
BOD ₅ , mg O ₂ /l	69	230	210	4 590	120	390	20-57 000	20-200
BOD/COD	0.06	0.02	0.04	0.64	0.04	0.04	0.02-0.8	
Ammonia, mg/l	633	1 787	1 530	379	2 070	1 690	50-2200	50-1000
Chloride, mg/l	610	3 270	1 430	620	1 630	2 870	150-4 500	4 000-8 000
TOC, mg/l	440	3 700	1 700	2 200	1 040	2 700	30-29 000	500-2 000
PO ₄ , mg/l	12.6	86.9	76.8	50.6	25.5	19.6	0.1-23 (4)	1-15 (4)
Ca, mg/l	275	375	340	1 730	51	220	10-7 200	100-800
SO ₄ , mg/l	20	9	<5	<5	29	500	8-7 750	1 000-5 000
AOX (2), mg/l	0.72	2.3	5.2	0.32	1.1	1.9		
Metals (3) :	Al (mg/l)	0.6	20	6	3.9	0.91	11	
	As	<2	50	58	9.8	110	430	<1 000 (5)
	Cd	<10	<20	<10	<10	<10	<400	5-100
	Cr (mg/l)	0.39	2.2	3.6	0.1	0.62	4	<1.5
	Cu (mg/l)	<0.2	0.3	0.14	0.14	<0.1	0.17	<10
	Fe (mg/l)	3.2	76	21	25	12	14	5-20
	Hg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<160
	Ni	<100	810	270	250	170	430	<13000
	Pb	<100	220	<100	<100	<100	<100	<5 000
	Se	<200	<400	<200	<200	<100	<100	<400
	Zn (mg/l)	0.14	1.7	0.88	2.5	0.19	0.71	<1 000
								0.5-3

(1) Laboratory measurements

(2) Adsorbable halogens

(3) $\mu\text{g/l}$ unless stated

(4) as total phosphorous

(5) only maximum values are reported

Interpretation of the data can be made by:

- comparison of behaviours between samples from the same site, e.g. between waste of different nature (site A) or between untreated and treated waste (site B),
- comparison of data between the two sites, the MBT process and the landfilling being different between the two plants,
- comparison with data from literature.

There are several references in the literature which give typical value ranges for the classical parameters on leachate coming from landfills of different ages, to which we can compare our results. We have focused on studies which report a large number of values, on a great number of parameters and a large number of sites, as for instance Kjeldsen *et al* (2002), Oman & Junestedt (2008), or results obtained on sites which receive MBT waste (Robinson *et al*, 2005). Some of these values are reported in the table for comparison.

Values cited by Kjeldsen *et al* were compiled from 15 studies published between 1979 and 1997. Since then, composition landfilled of waste has changed, especially in Europe where separated collections of different fractions are now made. Therefore, the polluting potential has decreased, for instance for chlorinated compounds. But ranges of values cited by Kjeldsen are very large and cover a lot of different situations. A study realised in Sweden covered a lot of parameters (400) measured on the leachates of 12 sites, receiving different types of waste (Oman & Junestedt, 2008). Robinson *et al* published in 2005 a study realized on leachates coming from different MBT sites. The basis is the sorting of organic matter from Municipal Solid Waste (MSW), which leads to MSOR (Mechanically sorted organic residues). This fraction of waste, when landfilled without treatment, gives rise to high organic, ammonia and chloride content of the leachates. On the contrary, when this fraction of waste undergoes stabilization process, the corresponding leachates from the landfilling are generally weaker than those of a classical waste deposit without treatment. The stabilization processes described by Robinson *et al* ranged from a “low” to “high” degree of composting. Because of the MBT processes which are used on site A and B, we have selected for comparison the values given by Robinson on leachates from landfilled waste which had a “low” to “moderate” stabilization process.

3.1 pH

pH of leachates are different for all the samples, but are never really acidic, comparatively to the first biodegradation phases on classical landfills without MBT (Kjeldsen). Values range from 7.2 on the large refuse cell of site A, to 7.95 on the composted cell of site A, and from 8 to 8.6 on the two cells of site B. The lower pH value is found on the leachate from pond n°4 of site A, receiving the process waters, which can correspond, to a certain extent, to an “acidic” biodegradation phase. As Robinson pointed out, composting the organic matter before landfilling avoids the acetogenic degradation process in the landfill cell. pH are even less acids on site B than on site A, maybe because there is a part of selective collection of biowaste in this area, so the waste which goes to the MBT plant has less organic residues than on site B, and acidogenic/acetogenic phenomena maybe lowered.

3.2 Conductivity

Conductivity of leachates from all our samples (from 8 to 30 mS/cm) are rather high : they still fall in the ranges given by Kjeldsen, but the value measured on the cell of composted fine waste of site A is higher than the range cited by Robinson. Conductivity is mostly due to the salt content of leachates, and little to the organic matter, which is not charged (except the acids): the stabilization given by the biodegradation of the organic matter does not change much the electrical charge of the liquid phase.

3.3 Suspended matter

We have measured the suspended matter content of the leachates, as we have started specific studies on this phase. This parameter is not often reported in the literature. Oman & Junestedt (2008) cite a range from 8 to 2100 mg/l, with an average of 196 and a median value of 32.

Obviously, leachates content a lot of suspended matter, but in our samples values are rather low, especially for the high fraction cell on site A and for the old cell on site B. The higher content is found, with no surprise, on the process water on site A, and on the leachate from the young cell (receiving MBT waste) on site B.

3.3 Organic content

Due to the biodegradation processes, organic content of leachates generated by mechanical-biological treated waste is lowered compared to the content of leachates from untreated waste. BOD is the parameter which decreases the most on treated waste. COD also decreases, but to a lesser extent, so the ratio BOD/COD falls below 0.1, which normally characterizes “stabilized” waste. COD diminishes less than BOD because it also relates to non degradable organic compounds and to inorganic matter, which are not treated by the biodegradation processes.

It is considered that leachates from stabilized waste should have values of BOD < 100 mg/l, and COD < 1000 mg/l, beside the value of BOD/COD of 0,1 (Ravelojaona L., 2005). It is not the case here: only leachate from pond n°1 of site A (corresponding to large refuse) falls within these values.

BOD values are generally low on all our samples, except on the process waters on site A: see Figure 1. Considering that all the cells of site A and cell K2 of site B are young, this confirms that composting waste prior to landfilling lowers significantly the biodegradable content of the waste.

Nevertheless, composting has less action on COD, which is confirmed here: COD of leachates from cell 2 on site A, and from cell K2 on site B, which correspond to the composted waste, are the highest (see Figure 2). This shows that these cells still have a polluting potential, which is confirmed by the biogas emissions, still high enough to be burnt in flares. COD is relatively low (value around 1000 mg/l) only for the leachate from cell 2 of site A, which corresponds to the large refuse, the most inert fraction of waste. Plastics in cell n° 3 probably still contain a little organic matter and salts, which go to the leachates of this cell.

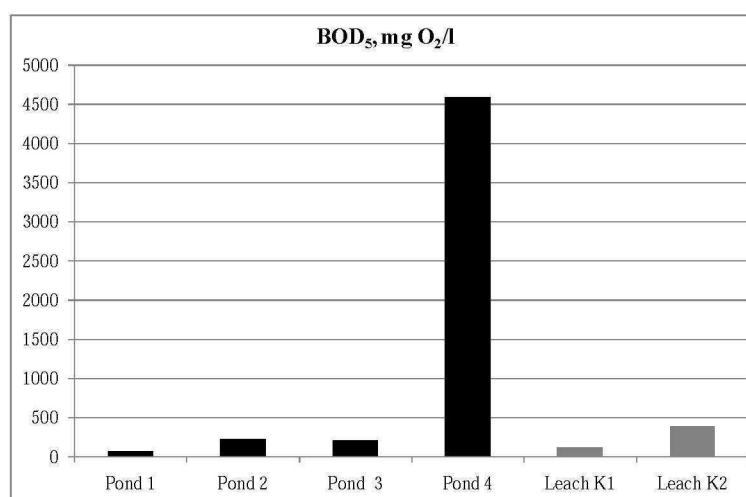


Figure 1. Biological oxygen demand of the various leachates of the two sites A and B

With low BOD values (except for the process waters on site A) and relatively high COD values, the ratio BOD/COD falls well below 0.1 for all the leachate samples: see Figure 3.

The lower value is encountered on the leachate of the composted waste of site A. For site B, this ratio is the same for the leachates from the zones K1 and K2, though BOD and COD values are a little higher on cell K2, which is younger. This shows that, due to composting prior to landfilling, cells K1 and K2 have reached the same proportion of biodegradation in relation to the polluting potential of the waste.

AOX (adsorbable organic halogens) is a global parameter. It does not give information about organic species, but there is a mandatory value of this parameter for liquid release in surface waters (Arrêté du 09/09/1997): concentration should be lower than 1 mg/l when the total daily flux is higher than 30 g/d (which corresponds to a liquid flux of 30 m³/d).

Here, leachates from site A, pond 1 (large refuse) and 4 (process waters) fulfil this limit value, and leachate from cell K1 of site B nearly fulfils it: see Figure 4. As seen previously, leachates from pond n°2 on site A and from cell K2 on site B (both receiving composted waste) have nearly the same value, 2.3 and 1.9 mg/l respectively, which is only twice the limit value for environmental release (though limit values are exceeded for other parameters such as BOD and COD).

The highest AOX value is shown by the leachates from pond n°3 of site A (plastics), which may come from chlorinated organic compounds traces in the plastic bottles (such as cleaning products) and by possible degradation of chlorinated plastics such as PVC.

3.4 Salts

Ammonia and chloride are compounds of a big concern in landfill leachates : there are generally present at high concentration, they are poorly degraded, and their release by leaching of the waste can last a long time. There is not a large release of these compounds in the process waters of site A, but they are mainly emitted by the stored waste.

Once again, leachates from the two cells receiving composted waste (cell 2 – site A and cell K2 – site B) have nearly the same concentration in ammonia and chloride.

There are also two remarkable values in ammonia concentrations:

- leachate from pond n° 3 (plastics) of site A has quite the same value as pond n°2 (composted waste),
- on site B, leachate from cell K1 (old waste) is more concentrated than leachate from K2 (young composted waste): composting the waste lowers a little ammonia concentrations.

The mandatory limit value for environmental release (Arrêté du 09/09/1997) for total nitrogen is 30 mg/l. All leachates largely exceed this value, imposing the treatment of these waters before any environmental release.

There is a higher concentration of chloride in leachate from cell K2 than K1 on site B. This may indicate either a slow decrease in the emission of chloride by the untreated waste, or a higher release due to composting processes prior to landfilling (giving access to chlorinated salts). Meanwhile, this phenomenon does not occur for ammonia. More measurements will be necessary in order to clarify this point.

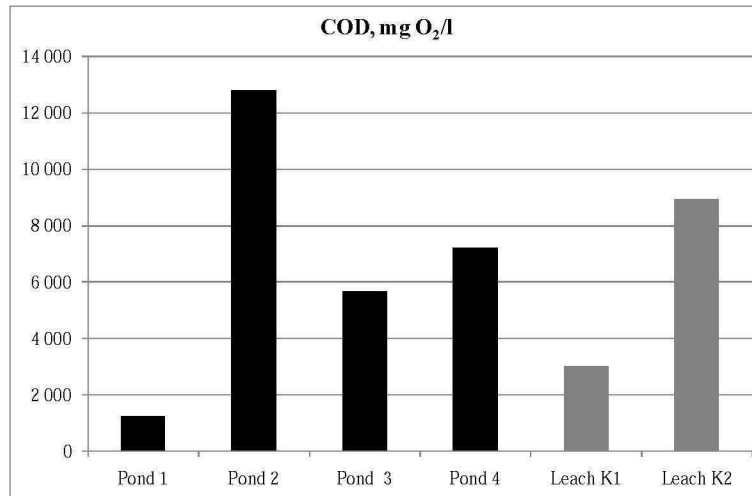


Figure 2. Chemical oxygen demand of the various leachates of the two sites A and B (legend : see 2.1)

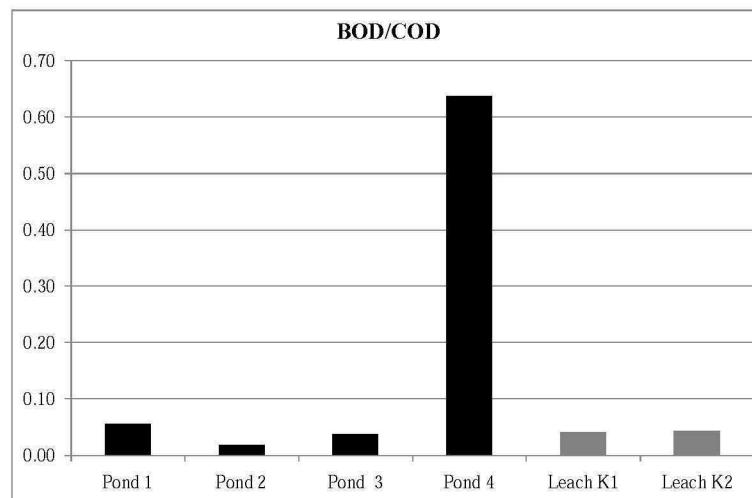


Figure 3. Values of the BOD/COD ratio on the various leachates from sites A and B

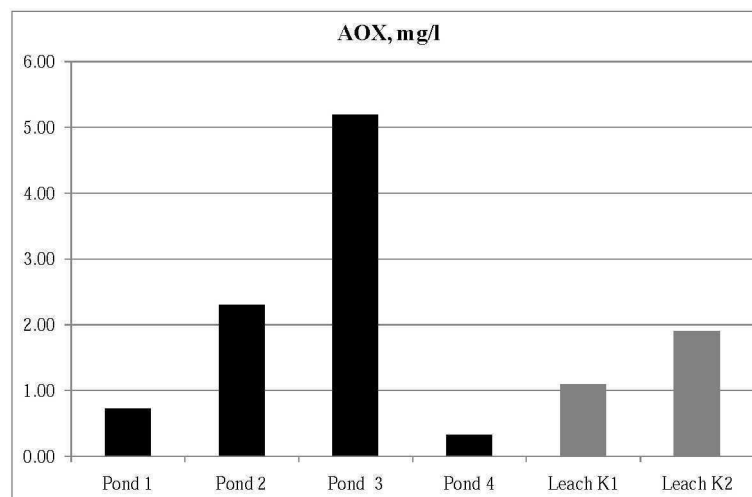


Figure 4. adsorbable organic halogens compounds on the various leachates from sites A and B

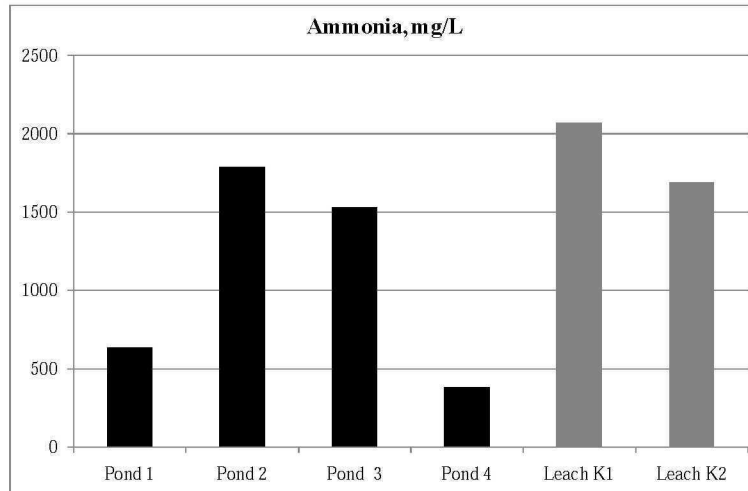


Figure 5. Ammonia concentrations of the various leachates from sites A and B

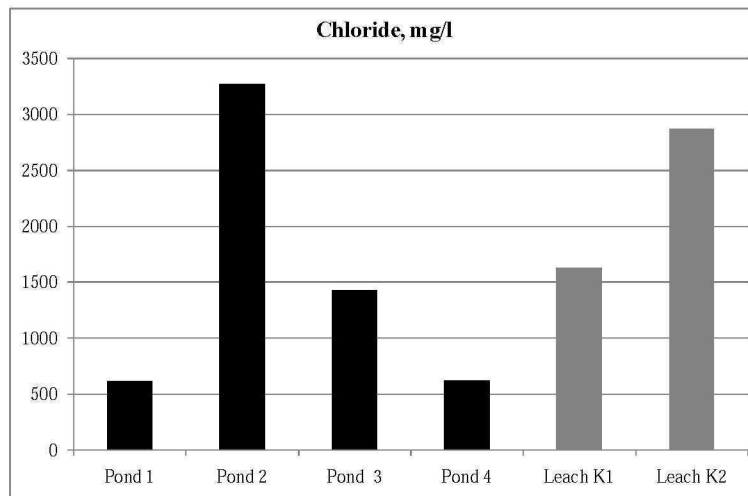


Figure 6. Chloride concentrations of the various leachates from sites A and B

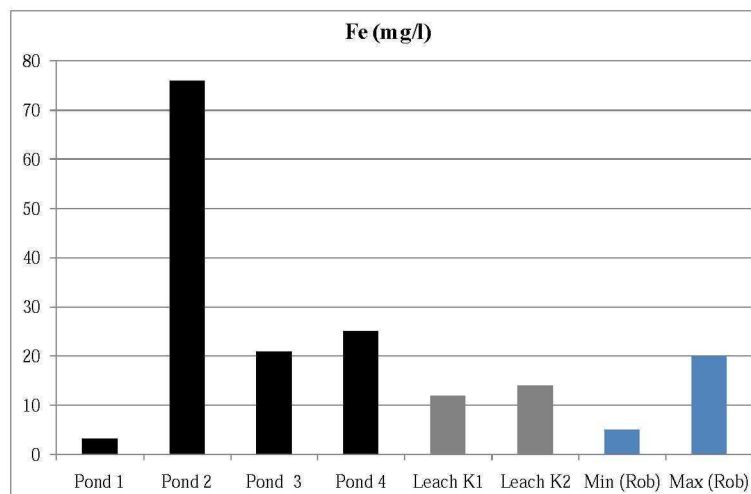


Figure 7. Iron concentrations of the various leachates from site A and B, compared to values cited by Robinson *et al* (Rob)

3.5 Metals

Aluminium and iron are the two metals which are the most concentrate on leachates from both sites (ranges of mg/l). They are considered as non toxic (iron) or weakly toxic (aluminium) and therefore, not often measured or published in the litterature.

Toxic heavy metals are all found in very low concentrations, and as low (except for arsenic in leachate K2) as the limit values for release in the surface waters in the French Arrêté of 1997. We cannot conclude on chromium, as only total chromium was analysed, and the mandatory limit values are for Cr^{6+} . Yet, all landfill leachates that we have sampled are treated, either on-site or off-site. Therefore, metals in these leachates will not induce a health or environmental problem.

Metals generally show low concentrations because a large fraction of metals are immobilized in waste by complexation phenomena. Then, a change in the conditions prevailing in waste (pH, redox) could free a large amount of metals (Kjeldsen et al, 2002).

3.6 Micro-analysis of the suspended matter

On the cellulose filter, carbon cannot be distinguished between the leachate solids and the cellulose support. Therefore, only the minerals can be studied. On the glass deposit, the slow drying the formation of crystals, mainly sodium and calcium chlorides, which hide the metals. Examples of the SEM pictures are given in Figure 8.

On site A, filtration of leachate from pond 3 (plastics) did not give a good sample, and could not be studied by SEM. On each sample filtrated on the cellulose membrane, at least 1,000 particles were analysed automatically: dimensions and occurrence of elements are given in Table 2 and Table 3.

The smaller dimension of the particles analysed on all samples is related to the porosity of the cellulose membrane: the minimum size is $0.5\ \mu\text{m}$. The maximum size of the particles can vary a lot from a sample to another, so for comparison we have considered the size in which 95% of the particles fall: see in Table 2. Particles from leachates of site B are smaller, and there are the smaller on leachates from cell K2 : 40 % of the particles have a dimension of $1\ \mu\text{m}$. We have not found references from the litterature to compare our data: this parameter will be measured on other leachates in order to find tendencies.

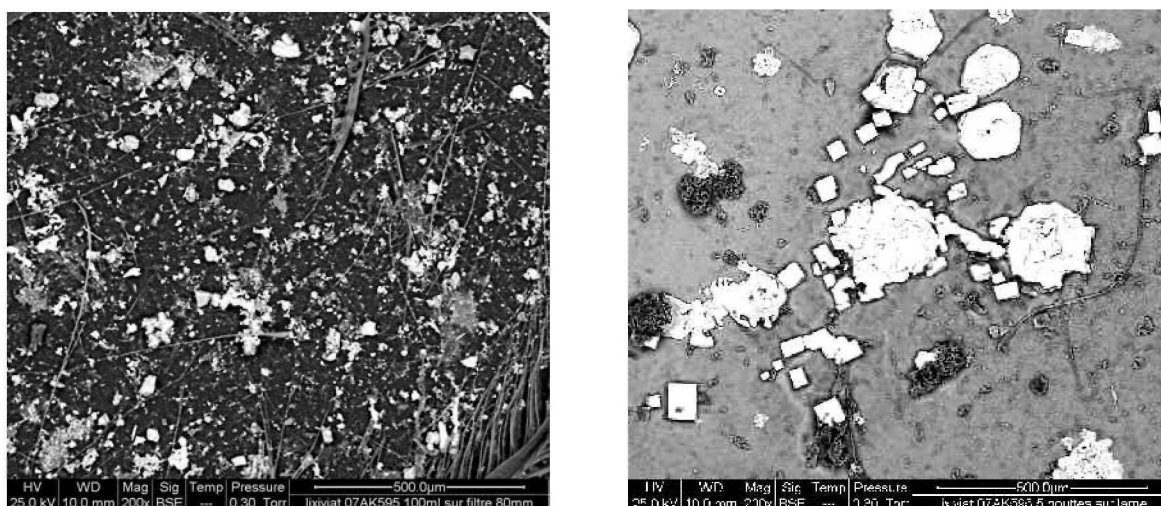


Figure 8. SEM of leachate solids deposited by a: filtration on cellulose membrane, and b: drying on glass

Table 2. size of 95% of the leachate particles from the sites A and B

	Site A			Site B	
	Pond 1	Pond 2	Pond 4	Leach. K1	Leach. K2
Max size μm , 95% particles	11	6.6	7	3	<4

Table 3. occurrence of elements on the various leachates from sites A and B

	Element	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Cu	Zn
Site A	Pond 1	N. D.	N. D.	24.3	4.5	15.7	N. D.	73.5	19.9	96.1	N. D.	55.8	3.9	3.4
	Pond 2	N. D.	N. D.	49.5	41.7	40.8	N. D.	70.9	92.7	92.3	N. D.	76.7	8.7	8.6
	Pond 4	N. D.	N. D.	22.5	82.9	35.2	N. D.	47.7	40.8	45.3	N. D.	47.5	30.3	1.4
Site B	Leach. K1	100.0	96.0	2.0	1.2	2.8	1.2	1.1	97.4	4.4	5.4	3.3	1.9	N. D.
	Leach. K2	97.8	81.1	3.2	17.1	17.6	1.9	15.7	93.7	32.6	21.2	11.4	N. D.	N. D.

N. D.: not determined

Occurrence of the elements is the number of times each specific element is detected by the X-ray probe on the surface of a particle. They are reported for the leachates of the two sites in Table 3. Analysis were performed at different times, so we have extended the number of elements which could be determined, as they bring additional information to classical salts and metals analysis.

X-ray microanalysis on the suspended matter show the same tendency between different leachates, as metals measured by ICP on unfiltered leachates. They also reveal the presence of oxygen (when determined) and chlorides on all the particles which were automatically analyzed by the microscope for the waste deposits which contain organic matter.

4. CONCLUSIONS

Leachates from MBT waste show a different behaviour, depending on the pollutant: some values are similar to those of young, untreated waste (COD, chloride) whereas others represent a certain degree of stabilization (pH, BOD, ammonia, AOX...). Biodegradable organics are the compounds which decrease the most during pre-treatment. Salts (and especially chlorides) are the compounds which diminish the less in leachates from treated waste, compared to untreated waste. Ammonia seems to decrease a little. Biological treatments do not degrade (or little) these compounds, which will remain the bigger after-care problems in landfills management.

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